BULLETIN

OF THE

# Society for the Promotion of Engineering Education

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## EDITORIAL

*The Annual Meeting.*—As the plans for the meeting progress it is evident that the section feature will bring out papers and discussion of great interest. The preliminary plans published in this number of the BULLETIN indicate the hopelessness of covering the entire field by sessions held "in series." The "parallel" section meetings will allow the specialists in the several fields to treat their own problems thoroughly and as the number of members in attendance at each section meeting will be relatively small there will be ample opportunity for all to take part in the discussion. The important thing now is to get to the meeting.

*Dean Eddy's Retirement.*—As this number of the BULLETIN

goes to press announcement is made of the retirement of Professor Eddy from his work at the University of Minnesota. He was one of the charter members of this society and since the beginning has taken an active and constructive part in its work. His fellow members wish him a long and happy period of well-earned leisure.

*Discussion of Bulletin Papers.*—As the contributions to the BULLETIN indicate, all of our members do not think exactly alike on some of the details and even of the principles of engineering education. This is as it should be and great good can be done by free discussion of mooted questions. President Riggs and Professors Franklin and MacNutt have stirred up much interest by their radical points of view in regard to mathematics and physics respectively. The June BULLETIN will contain much more along the same lines.

*A Simple but Effective Shop Building.*—All members who are concerned with the problem of putting up cheap but satisfactory laboratory and shop buildings will be interested in the article by Mr. Wells in this issue. For $60,000 a very satisfactory building has been put up at Cornell to house some of the shops. Great care was put into the design of this building as it becomes the type to be followed in the remodelling of the group of Sibley College buildings.

*The June* BULLETIN will be the last number to be issued during the present college year. Members of the Society having matters in mind which they wish to bring to the attention of other members should send in communications at once.

## NEW MEMBERS.

The Council has elected the applicants whose names are listed on pp. 411 and 412 of the April BULLETIN and below.

AUSTIN, F. E., Professor of Electrical Engineering, Dartmouth College, Hanover, N. H. ..... 1912

BOYER, F. Q., Instructor in Mechanical Engineering, Sheffield Scientific School, Yale University, New Haven, Conn. ..... 1912

BOZELL, H. V., Professor of Electrical Engineering and Director of the School of Electrical Engineering, University of Oklahoma, Norman, Okla. ..... 1912

CROCKETT, CHAS. W., Professor of Mathematics and Astronomy Rensselaer Polytechnic Institute, Troy, N. Y. ..... 1912
EHLERS, H. E., Professor of Experimental Engineering, University of Pennsylvania, Philadelphia, Pa. ..... 1912
FRAZIER, F. F., Assistant in Civil Engineering, Kansas State Agricultural College, Manhattan, Kans. ..... 1912
GODDARD, A. L., Supt. of Shops and Assistant Professor of Mechanical Practice, College of Engineering, University of Wisconsin, Madison, Wis. ..... 1912
HAIGLER, CHAS. E., Professor of Mathematics, Wentworth Institute, Boston, Mass. ..... 1912
MCCLELLAND, J. F., Professor of Mining Engineering, Sheffield Scientific School, Yale University, New Haven, Conn. ..... 1912
O'SHAUGHNESSY, LOUIS, Instructor in Mathematics, University of Pennsylvania, Philadelphia, Pa. ..... 1912
PRENTICE, D. B., Assistant Instructor of Mechanical Engineering, Sheffield Scientific School, Yale University, New Haven, Conn. 1912
RIDDERVOLD, A. S., Assistant Professor of Civil Engineering, University of Nebraska, Lincoln, Nebr. ..... 1912
ROLLINS, E. B., Assistant Professor of Electrical Engineering, Tufts College, Tufts College, Mass. ..... 1912
TEMPLE, W E. S., Assistant Professor of Electrical Engineering, University of Pennsylvania, Philadelphia, Pa. ..... 1912
VAN HAGAN, L. F., Assistant Professor of Railway Engineering, University of Wisconsin, Madison, Wis. ..... 1912
WILLIS, A. J., Instructor in Civil Engineering, Cooper Union, New York, N. Y. ..... 1912

## PRELIMINARY PLANS FOR THE BOSTON MEETING.

As was previously announced, an important feature of the meeting to be held this year in Boston on June 26, 27 and 28 will be the section sessions devoted to laboratory work in the several divisions of engineering. The section chairmen are having excellent success in securing papers from prominent specialists.

Professor Sperr reports that the section on mining laboratories will follow an outline somewhat as follows:

### Mining Engineering Laboratories.

Sub-division.

1. Civil engineering—field surveying, testing materials, construction and erection.
2. Mechanical engineering—shops (blacksmith, carpenter, machine), drawing rooms.
3. Electrical engineering—installation and wiring, operating, testing, repairing.
4. Hydraulics.
5. Metallurgy—assaying, smelting.
6. Ceramics.
7. Ore testing.
8. Ore dressing.
9. Coal washing.
10. Mining—drilling, blasting, timbering, modelling, mine surveying, inspection of mines, work in mines.

Professor Sperr states that this outline was designed to be as broad and general as possible in order to call out a free and general expression of opinion from the members, as to the proper scope to be given to the discussion. Many valuable contributions have been received. It now seems probable that one session each will be devoted to ore dressing laboratories, mining and metallurgical laboratories, and discussion of standard arrangements and requirements in other engineering laboratories for students in mining engineering.

Professor F. P. McKibben, who will have charge of the section meetings devoted to materials testing and hydraulic laboratories, requests that members who desire to coöperate with him in making these sections a success should communicate with him at once. He is in communication with a number of members who are expected to take an active part in the meeting.

Professor A. M. Greene, Jr., in charge of the section meetings on mechanical laboratories, expects to have papers on the following subjects: The Purpose and Aim of Mechanical Laboratory Work; Laboratory Apparatus; Preparation of Apparatus for Class Work; Temporary Equipment; The

Value of 24-hour Tests for Student Instruction; Laboratory Examinations; Laboratory Reports; Experiment Stations; Original Investigations for Undergraduates; Section Work versus Individual Work; The General Characteristics of the Mechanical Laboratories of American Schools.

Professor J. O. Phelon is planning to have a number of the younger members of the Society present papers on the subject of electrical laboratories. A series of ten or twelve papers will be presented.

### The Symposiums.

*Scientific Management.*—Mr. Frank B. Gilbreth, who will preside over the session devoted to this subject, has arranged the following preliminary program:

Introduction by the chairman.

The Place of Scientific Management in the Engineering College Curriculum.

The Engineer the Ideal Manager.

Scientific Management in the Engineering Colleges Today.

The Relation of College Training in Scientific Management to Field Experience.

Auxiliaries to Colleges in Training Scientific Managers.

The Men Who Succeed in Scientific Management.

Openings for Scientific Managers which the World Offers.

The Place of the College in Collecting and Conserving the Data of Scientific Management.

Demands of the Present Situation upon the Scientific Manager.

*Efficiency in Teaching.*—Dean G. C. Anthony reports as follows regarding the plans for the symposium on this subject:

It is proposed to devote the time of one session to the consideration of questions relating to the promotion and supervision of teachers in engineering schools. These are problems which vitally influence the success of our institutions, the development of high grade instructors, and growth in the character of students.

Several papers have been presented to the Society which

touch upon various phases of this subject, and the presidential address by Professor Talbot at the Pittsburgh meeting dealt with the ideal character of the teacher which should be realized more frequently than present methods make possible. Some of the questions involved are as follows: What is the engineering college doing to develop good teaching? What assistance is rendered the young instructor in protecting him from the mistakes of his predecessors? What guidance is he receiving in the governing of his classes, and in pedagogical matters? How can he be advised concerning the importance of character training, the adoption of improved class room methods, and the ways and means for his own development in the theory and practice of his profession of teaching?

The "laissez faire" policy now adopted, or inherited, by most colleges is not conducive to the efficient growth of our teachers; and it would appear that not only is little done to assist the inexperienced teacher, but the governing authorities may remain ignorant of his inefficiency long after he has been condemned by his own pupils, an inefficiency, too, for which they may be partly responsible

An interesting article in the Pedagogical Seminary for December 1911, by Dr. Samuel P. Capen, of Clark College, has brought to our attention some rather startling facts relating to one phase of this subject. The author reports the result of an investigation of the system, or lack of system, of supervision in sixty colleges and universities. More than half of these institutions believe supervision desirable, although twenty-two believe supervision would be resented, a state of things which it is difficult for the engineering professor to realize. In nineteen institutions supervision is exercised by no one, and in fourteen others supervision is made by a committee of the trustees or alumni which, I suppose, might also be regarded as no supervision. The methods of promotion, too, seem to be questionable, as twenty-four institutions reported promotion as being made on a general impression of the work done, and the personality of the man; fifteen institutions made promotion dependent on the result of inspection

combined with a general impression; while eight promoted on the recommendation of the heads of departments. Dr. Capen comments on the situation, as follows:

"Nearly all institutions are peculiarly subject to malpractice at the hands of the fledgeling instructor. The present requirements for holding most college positions do not include previous teaching experience, or even training in the art of instruction. To be sure, teaching like any other art can only be learned by practice, but there are certain underlying principles which enable the beginner to avoid many mistakes and help him shortly to find the best way to present his subject. Most young college instructors are totally unacquainted with these. However well they may know their subjects, a little friendly oversight at the outset would shorten the path to reasonable perfection in the art of presentation. Obviously, both the institution and the instructor would gain by the arrangement. It is discouraging to flounder just beyond one's depth, when the touch of a helping hand might bring one's feet in contact with the bottom. The young instructor often flounders for years before finding his feet and in the process he has wasted much vital energy which should have gone to the advancement of his work. The institution owes its young teachers this help as much as it owes its students protection against incompetence."

It has seemed to the President, and others of the council, that a symposium on this general topic would be helpful to the older as well as the younger teachers, and would be suggestive of methods which would be invaluable in promoting the welfare and development of schools and teachers. We should also hear from the younger instructors concerning their own grievance as to neglect or possible warping influence of too restricting a vocation, and lack of guidance which may prevent broadening in their professional work. May we not unite to make this next meeting of the Society a notable one in raising the efficiency of instruction, a need to which every live educator must be keenly sensitive.

## LETTER TO THE EDITOR.

SECRETARY S. P. E. E.,

*Dear Sir:* We have made some changes in our entrance requirements at the University of Michigan which may interest the members of the Society. These changes are the result of several weeks, even months of work, and so far as we can discover, meet the situation here in what promises to be a reasonably satisfactory manner. (See appended list.)

There are two things of particular interest. First is the dropping of trigonometry as an entrance requirement. We find that a good portion of our entering students have to be conditioned in this subject and the proportion has not changed much in six or eight years, so that it was practically useless to continue to require it with the expectation that the high schools would gradually work up to it. The other change is in modern languages, and this to me is of particular interest. Our engineering students are given a choice of German, French or Spanish. We had some difficulty in Spanish as compared with German and French, owing to the fact that not so much time was required to reach the same degree of proficiency in Spanish. To overcome this and put it on a par with German and French, we now permit students who offer three or more years of Latin to complete his modern language requirement, if in Spanish, in one year's time; that is, with two 4-hour courses; in other words, we count the Latin, beyond the second year, as a modern language in Spanish.

Our faculty has just recently, and after full discussion, adopted new requirements in modern languages requiring of the student only one modern language, instead of two, as now. The plan is something like this: We have in the past required 24 hours of modern language including high school. This cut has been made in the expectation of putting the balance of the 24 hours either into other language work or into culture work. We still have some work to do on this subject before it is completed.

Another thing of interest is that we are considering a combined literary-engineering course in which a student can spend three years in the literary department, take his work in the fourth year in the engineering department and graduate as an A.B. or B.S. in the literary department at the end of four years. Then by spending a fifth year in the engineering department he would also graduate in engineering. This is not to take the place of our present five-year course altogether but may lead to some changes in that course. We look forward to its proving a good move.

Yours very truly,

M. E. COOLEY.

## NEW REQUIREMENTS FOR ADMISSION TO THE ENGINEERING DEPARTMENT OF THE UNIVERSITY OF MICHIGAN, ADOPTED MARCH 6, 1912.

### ADMISSION OF CANDIDATES FOR A DEGREE.

Candidates for admission as regular undergraduate students must be at least sixteen years of age and must pass examinations in fifteen units as indicated below or must be recommended by an accredited preparatory school as graduates who have satisfactorily completed these requirements for admission. Students who otherwise meet the above requirements but are deficient in not more than one and one half units, may be admitted conditionally, but must make up their deficiencies within one year. These requirements are stated in units, a unit meaning the equivalent of five recitations a week for one year in one branch of study. Two hours of laboratory, drawing or shop work are counted as equivalent to one of recitation.

### PRESCRIBED UNITS FOR ADMISSION.

English 3 units,
Mathematics 3 units,
Physics 1 unit,
History 1 unit,

Latin
German
French
Spanish } 2 units of one language,

Chemistry 1
Trigonometry ½
German 1 or 2
French 1 or 2
Latin 1 or 2
Manual training 1 } 1½ or 2 units.

Total prescribed, 11½ or 12 units.

The manual training accepted for this unit must be of such a character as to excuse the student from shop 1 (wood shop and forge shop) in the university. Students who do not present trigonometry and chemistry for entrance will take a two-hour course in trigonometry and two four-hour courses in chemistry during their first year of residence.

The remaining 3 or 3½ units may be presented in any subjects for which credit toward graduation is given by the accredited school and which are taught in a manner approved by the university; but no more than three of the fifteen units required for admission will be accepted in vocational subjects and no more than two units in any one of them.

Graduates of schools outside of Michigan must send courses of study or letters from instructors describing the work done when credit is asked in the vocational subjects—manual training, drawing, agriculture and commercial branches.

Chemistry and plane trigonometry are placed in an alternative group with German, French, Latin and manual training, so that all high schools with three or more teachers may offer full preparation for the engineering department, even if they cannot teach chemistry and trigonometry. It is highly desirable, however, that students present these subjects for admission so as to avoid irregular classification which sometimes results in conflicts and loss of credit.

# THE LACK OF RELATION BETWEEN MATHEMATICAL AND ENGINEERING TALENT.*

BY A. J. WOOD.
Pennsylvania State College.

While many will agree fully to the general proposition of President Riggs and to much that he has said in defense of it, yet we must admit the limitations of certain of his statements.

True it is that engineering is the application of educated common sense to the affairs of life, but is that all? If it is, engineering is no different in its requirements than are a hundred other common lines of practical and professional work. Personally, I have little faith in *educated* common sense. If there is such a thing, one would probably learn it quicker and better in places other than the college. Furthermore, what has mathematics to do with this phase of the question, more than has physics, chemistry, machine design, or any other subject in a college course?

Reference is made to a civil engineer who, designing a bridge, can employ a mathematical artisan at $3.00 a day to compute the size of every member of the structure. If that so-called engineer relies on that calculation without being able to check the work, he may prove a menace to the public. He may be a money-maker, a ward engineer, or an "expert" in print, but has no place in the list of real engineers.

Yes, make the student struggle in the mathematical gymnasium as much as necessary, but why? Because he will make a *better* engineer if he does. If this be true, there is little left for the defense of the assertion that the mathematical talent may indicate an order of intellect not suited for the practice of engineering.

Further, let us remember that engineering is not only getting and holding jobs or handling a big contract, or knowing

* See paper by President Riggs, p. 248, Jan. BULLETIN.

what may be required ten years ahead. It is even something more than a mechanic art. There is a science of engineering as well as a practice of engineering. A maker of good instruments is just as necessary as a good user, the designer of a new valve motion or a better meter is usually a keener type of man than the user of these instruments. Experience shows that the men who develop the art are seldom those who have aversion to mathematics.

The writer concurs in the conclusion reached by President Riggs in reference to the boy to whom mathematics comes hard. If it comes hard and he plods through it and works until he sees the "why" of the mathematics, he has a good basis for turning out a reliable engineer. But if, without wading through, he expects to become a real engineer, he is deceiving himself and what is worse, the college is doing him an injustice.

How much of a humbug is there in our college courses? Just as much as we are humbugs in our teaching. Greater than the subject or the course, is the man.

The trouble today is not in the handling or the seeing of the mathematics, but rather in that higher art of linking the true physical meaning to the equation and process,—of knowing when the mathematics expresses the fact, the law, the truth. This part of the problem is for the engineering more than for the mathematical teacher.

## REFORM OF TECHNICAL COLLEGE METHODS.*

In a recent issue *Engineering News* prints a paper which covers some of the points now under discussion by the Society. After defining "the best education as that which has the farthest reaching effect in advancing the human race," it states that technical education should concern itself with the equipment and training which will best enable the student to be resourceful and inventive. From infancy the principal business of life consists in working out problems, hence the importance of mathematics. "Mathematics is to the mind what physical exercise is to the body." The contention that technical students should take up mathematics only as far as quadratics would apply only to the men of average education who make no pretence to technical training. However, no engineer who is to practice his profession in anything like an extensive manner can be considered well equipped unless he has a good deal more mathematics than is obtained up to the end of quadratics. An extensive study of mathematics is not advocated by the author but merely sufficient to fit the engineer for the practice of his profession. The fact that the engineer may need algebra, geometry, trigonometry and calculus in some of his special problems only at frequent intervals is not a sufficient excuse to drop them entirely, because when they are needed their importance is so great that the ability or inability to handle them may be the turning point in the career of the engineer. Where an engineer has a working knowledge of his calculus and the confidence due to this ability, he will very often successfully essay an accomplishment which would not be attempted by one with a superficial knowledge of the subject.

As every phenomenon is the result of force acting upon

* Abstract of a paper delivered before Philadelphia Lehigh Club, by J. W. Ledoux, Ch. Engr. American Pipe and Construction Co. *Eng. News.*, Mar. 14, 1912, p. 491.

matter according to one or more of the immutable and eternal laws of nature, it would seem that the only form of education that is worth while is the study, not of the phenomena, but of the matter, force and laws of which the phenomena are a result. The author believes that the time devoted to the study of legal matters in college is simply wasted. The lawyer with his special training is always called in if the matter is of any consequence. The subject of political economy is one of the most vital importance and one in which the fundamental principles appear to be entirely discredited by the majority of people.

In the author's experience with technically-trained men in his employ he concludes that the sterling qualities which make the engineer invaluable have nothing whatever to do with technical studies. A man must be a "live wire," and have an excess of the qualities known as persistence and reliability, so as to act when sent to perform a task. He believes the college course should not be practical in the ordinary sense of the word. Engineers should be taught fundamental principles and be equipped with tools of science in college, and then go into practical work immediately upon graduation to obtain the practical education. A thorough knowledge of fundamental principles enables a man to obtain his practical training with much more effective manner and in a short time. The author then specifies an outline for a four-year civil engineering course, including entrance examinations. In the outline he gives considerable attention to English, including the ability to write reports and address bodies of men on engineering subjects. He points out that only essential subjects are given, not only in the course but in the entrance examinations. Outside subjects as French, German, Latin, English literature, general history, sociology, laws of business, etc., can be taken as elective courses as they are not essential to engineering.

The author avers that, after a young man has had a good common-school education up to the end of his 14th year, it would add greatly to his future college education if he spent

about four years in practical work. It does not make much difference in what capacity he works so long as he is able to get a general practical experience in his own line of work. It will also enable him to study the human nature problem which is of great value. If he amounts to anything he will probably have earned considerable wages during his four years of practical work.

"The point of my paper to which I wish to call particular attention is that in technical education, veneering should be avoided. Fundamentally useful subjects should be selected in only a sufficient number so that the student can be thoroughly grounded in their principles by solving enough original problems to obtain a working knowledge."

## FACULTY COMMITTEE ON EMPLOYMENT.

BY WALTER S. FORD,

Assistant Professor of Electrical Engineering, Cornell University.

The prime object of a technical education is to give the young man some preparation for taking up the real responsibilities of life. It is perfectly natural that the greater number of these men will take their places in the great engineering world; either in the pure engineering, the sales or the manufacturing departments. The college is very properly interested in the progress of its graduates, and in seeing that they are well located in good positions. With this end in view many of the large technical schools are now actively engaged in assisting their alumni to secure the positions for which they have been trained.

Some eight or ten years ago a committee, rather unique for that time, was appointed by the faculty of Sibley College, Cornell University, and named the Employment Committee. The reasons which led to its formation were threefold. (1) Numerous inquiries were being received by the College, throughout the year, from manufacturing and engineering companies who desired to get into communication with technical graduates with more or less experience of a practical nature since graduation. The number of these letters received was large and was constantly increasing. (2) Quite a number of inquiries were also being received from graduates who desired to find positions of an engineering character, either because they were unemployed or because they wished to change for one reason or another. (3) At about this time a few of the large manufacturing companies were beginning to realize that the young men just leaving college would soon be their strong men, their superintendents, engineers and directors, and that what they must do was to give these young technical men special training, fitting them for the positions

of trust and responsibility which they were to fill later. With these conditions in view the Committee was organized for work and it has grown to be a strong connecting link between the alumni and the college, and also a strong and a useful bond between the college and the great industrial world.

It has been the policy, from the first, to have the Employment Committee composed of representatives of the several departments of the College. The present committee has for its chairman a member of the electrical engineering department, and the other members are taken from the following departments: power engineering, experimental engineering, electrical engineering and machine construction. The wisdom of this method of making up the Committee is at once apparent, as it brings together a body of men who have been in close touch with the student on the various sides of his engineering education and who can, therefore, judge accurately as to his fitness for one kind of employment or another, upon his graduation. Accurate judgment of this kind is very important, as the College very often receives an inquiry from a company which is considering the application of a young graduate, asking, for example, whether he is better adapted to the shop or to the commercial side of the business. Again a company will give a description of the position which is open, together with the qualifications desired in the applicant, and will ask the College to recommend a young man who is apparently best qualified to fill the position in a satisfactory manner.

The real work of the Committee, however, falls to one member, the chairman, as this work consists in keeping records and in correspondence which cannot well be divided. The other members constitute an advisory board with whom the chairman confers when necessary. For the assistance of the Committee in carrying out this work most efficiently it has been found expedient to keep certain records and lists. The card system, which lends itself very readily to a condition of this nature, where flexibility is of very great importance, is used for all records. All cards are the standard 4 by 6 size. The

first and most important record is the alumni experience record. Fig. 1 shows the card which is used for this purpose. Its distinguishing color is yellow. As each class graduates, cards are prepared for its members, the entries being typewritten. The preparation of the cards of the older alumni has been a rather difficult task, but by consulting all available records and through the assistance of many of the alumni a large proportion of the records are now on file. Although this list is not complete it forms a most valuable reference record not alone to the Employment Committee but to the faculty of the College as a whole. In keeping up the record,

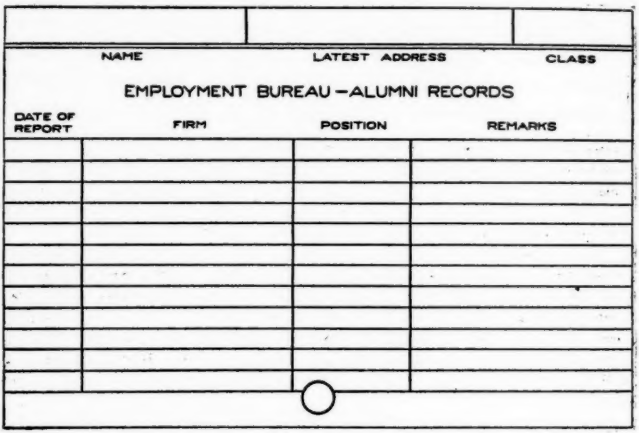



FIG. 1.

the item "latest address" is entered in pencil and the entry includes the date on which the address was obtained. As the body of the card is gradually filled it furnishes a concise history of the man's progress after leaving college. Such a history is invaluable when the faculty is asked to recommend a man for an important position.

Fig. 2 shows the white card on which the second important

record is kept. This is a file of applications of alumni for new positions. The cards are destroyed as soon as the applicants secure the desired employment or after the cards have been in the files for about a year without result. When an

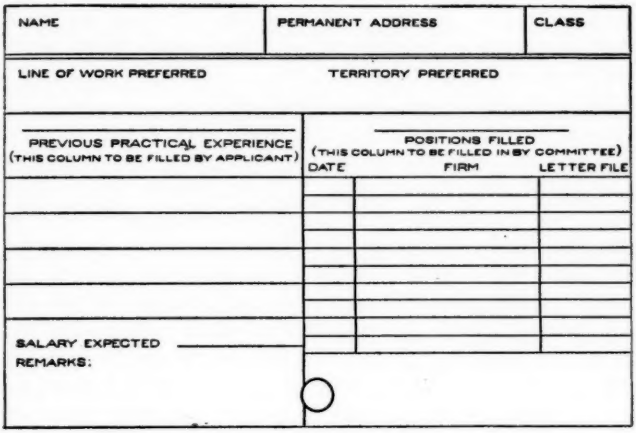



FIG. 2.

alumnus writes to the Committee or to the College stating that he is looking for a new position, one of these cards is sent him with the request that he fill in the blanks and return it at once to the chairman of the Committee. That portion of the card under "Positions Filled" was designed to give a record of the result of the Committee's efforts. When inquiries for men are received the Committee can quickly look over the white cards of the men who want positions and select the names of several who seem best fitted for the particular opening in view. These names, with the addresses, are then forwarded to the company making the inquiry or else the men themselves are notified of the opening and requested to correspond with the company if they are interested in the prospect. The particular method of bringing the alumni and prospective employers into touch with each other depends, in each case, on the wording of the inquiry from the employer.

A third card used by the Committee is a ruled blue card, on which is recorded the name of a company or individual requesting to be put into touch with young men about to be graduated. Besides the name of the company, a record is kept on each card of the dates of inquiry and number of men asked for. Many of the companies which employ technical graduates make a practice of requesting applications each year, hence these cards give an idea of what companies will be likely to employ men year after year.

For the purpose of keeping in touch with the alumni the Employment Committee sends out each year what has come to be called "the alumni letter." This contains first of all a letter from the Director of the College to the alumni. In this letter the Director gives an idea of the important changes in equipment and in policies which might naturally interest the alumni. Often a little folder containing paragraphs from the various departments, giving in more detail the happenings in the departments and their plans for the future, is enclosed with the letter. A blank form is always enclosed together with a return envelope, asking for the following items of information:

Your last report was dated .....
(1) Present date .....
(2) Name .....
(3) Date of graduation .....
(4) Present position .....
(5) Present address .....

Headings 6, 7, 8, 9 are for items of professional experience during period since last report.

(6) Positions held if other than present position.

(7) Engineering and scientific societies joined.

(8) Books and chief papers written.

(9) Inventions and special pieces of professional work.

(10) If desirous of finding engineering employees, state character of positions open and of men required with approximate pay offered.

(11) If desirous of finding a new position, state character of work or position desired and approximate pay expected.

(12) Do you desire that your answer to question (11) be considered confidential? .....

Remarks and items of general interest.

Thus far only the methods of handling the employment questions in connection with alumni have been considered. There is another and very important work done by the Committee. That is the work of assisting each year the men who are to be graduated in obtaining suitable positions. This work consists chiefly in notifying the students of all opportunities that come to the attention of the Committee or the College, and in advising them of the best method of making application. A great many of the companies at the present time have standard application forms and these are usually distributed to those who are interested, by the Committee. Many of the employers of young technical graduates come to the College or send representatives. This is done that they may get a good idea of the appearance and personality of the young men, and form some idea of their fitness for the positions to be filled. The Chairman of the Employment Committee meets these prospective employers and arranges for conferences between them and the students, and when it is desired, looks up the records of such students as they may be interested in.

The work of the Committee continues throughout the year regardless of vacations as there are numerous inquiries during the summer months. The heavy part of the work, however, is almost wholly confined to the spring term. The results of the work of this committee in Sibley College have been most gratifying. A large number of alumni find employment along the lines they desire each year, and the great number of letters received by the college from companies desiring to be put in touch with technical graduates are taken care of promptly and systematically. More than this the Committee's files of alumni records are becoming increasingly valuable each year, not alone for the records themselves but as an alumni directory.

## COLLEGE NEWS.

*Colorado School of Mines.*—The School of Mines has been fortunate in securing as the Commencement speaker this year Mr. Wm. L. Saunders, president of the Ingersoll-Rand Company and director in several important corporations. This will be Mr. Saunders' first public address since his return from a trip around the world following the visit of the mining engineers to Japan.—A party of students from the School recently spent some days inspecting the Trinidad coal field under the direction of Professor Allen.

*University of Idaho.*—The eight-week short course for miners has come to a close with an attendance of thirteen prospectors and others directly interested in mining, from Idaho and other states as far distant as California. Those in attendance expressed great satisfaction with the work.—The department of mechanical engineering has been conducting a night school for apprentices of the harvester works in Moscow. The instruction for three hours three nights in the week covers machine shop practice and shop mathematics.—On January 30 and 31 a Good Roads School for road overseers was conducted by the department of civil engineering in coöperation with the office of public roads, U. S. Department of Agriculture and the county commissioners of Latah County. Dr. L. I. Hewes, senior highway engineer, Office of Public Roads, was present and gave four lectures.

*University of Illinois.*—Among the interesting speakers before the engineering and architectural students in the past few weeks have been the following: C. F. Loweth, chief engineer of the Chicago, Milwaukee and St. Paul Railway, on "Personal Efficiency"; I. K. Pond, ex-president of the American Institute of Architects, on "The Practical Development of Historical Forms of Ornament in Connection with the Architectural Development of Various Countries"; Peter

Junkersfeld, electrical engineer of the Commonwealth Edison Company of Chicago, on "Engineering and Business Development."

*State University of Kentucky.*—The legislature just adjourned added fifty thousand dollars to the annual appropriation made by the State to the University. This same body provided an annual appropriation of fifty thousand dollars a year for university extension work in agriculture.—The junior class of the College of Mechanical and Electrical Engineering spent the week beginning Tuesday, March 19, on a trip of inspection to Cincinnati, Hamilton and Dayton. The senior class spent the week beginning Monday, March 25, on a trip of inspection to Chicago and vicinity. These inspection trips have developed from a casual visit to manufacturing industries to a very definite study of processes in manufacturing establishments and the status of large power plants. The students are required to prepare a very carefully detailed report of certain processes and practices that are assigned to them for study.—A summer school will be conducted as usual this year. Every student is dealt with as an individual and instruction is provided in any technical subject. Quite a number of operating engineers take advantage of the course.

*University of Minnesota.*—The main building is rapidly approaching completion and the two wings, authorized by subsequent action of the State Legislature, are in process of construction. The main building is a fine, large substantial structure, well-planned for the purposes for which it is to be used. Of the two wings, the south one will be used by the Department of Drawing, and the North one for the general library of the College of Engineering. When completed, it will be one of the largest and finest library structures of this kind in the country. It is planned for 60,000 volumes, 40,000 in the stacks, on the first floor, 10,000 on the second floor and 10,000 in the gallery on third floor, which overlooks and surrounds the second floor. The second and third floors are thus thrown into one beautiful room, to be made doubly attractive

by the high ceiling, ample light and generous equipment.—Dr. Henry Turner Eddy, dean of the graduate school of the university and head professor of mathematics and mechanics, in the College of Engineering, is to retire at the end of the present school year; he will have reached the age of 68, at that time, this being the age limit, fixed by the board of regents. Doctor Eddy will be greatly missed, and it is with deep regret that the College is to part with his inspiring personality and his highly valuable services. He retires in the fullness of health and power, with a mind as alert in the discovery of truth as in his earlier years. He has had a highly honorable, useful and long professional career, upon which his colleagues heartily congratulate him and will unitedly bid him a sincere God-speed for the future. The Minnesota Engineer for March contains a carefully-prepared biographical sketch of Dr. Eddy by Dr. Arthur E. Haynes professor of engineering mathematics and one of his co-workers for the past sixteen years.

*Pratt Institute.*—Pratt Institute will celebrate this year the twenty-fifth anniversary of its founding and a large number of alumni and former instructors are expected back to help observe this occasion. The special feature of the anniversary program will be the alumni dinner, Saturday evening, June 15, in which the alumni and instructors of the entire Institute will unite to the number of 2,000 to 3,000. Pratt Institute, established twenty-five years ago by Charles Pratt, a self-educated man, has extended the advantages of its training to nearly eighty thousand individuals, and stands to-day a monument to the successful realization of the founder's desire to "help the other fellow." Alumni and former instructors who have gotten out of touch with the Institute are cordially urged to communicate with the officers in order that they may be sent invitations and announcements.

*Washington University (St. Louis, Mo.).*—The following lectures by non-resident speakers form an important feature of the spring work. Problems in Sewer Design, by Mr. W.

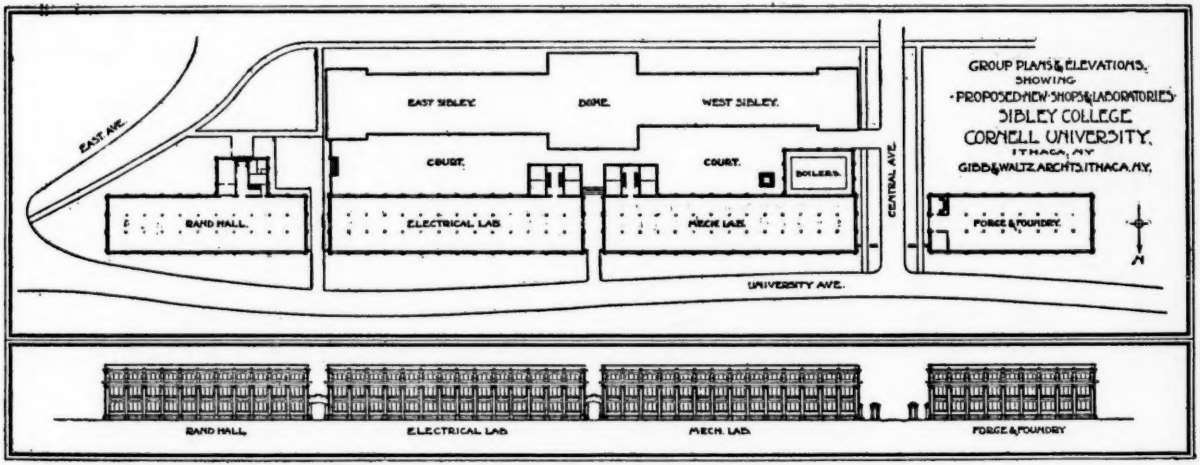
W. Horner, principal assistant engineer, St. Louis Sewer Dept.; The Ammonia Soda Process, by Dr. F. W. Frerichs; Mechanical Refrigeration, by Mr. R. H. Tait, president of the Tait-Nordmeyer Engineering Co.; The New Gary Plant of the American Bridge Co., by Mr. Albert Reichman, Chicago resident engineer of the American Bridge Company; What an Engineer Should Know About Public Utilities, by Mr. Jas. E. Allison, chief engineer, public service commission of St. Louis; Calculation of Alternating Current Transmission Circuits, by Mr. Guido Pantaleoni, vice-president, Westinghouse Electric & Mfg. Co.; Engineering in the Service of Chemistry, by Mr. Edward Mallinckrodt, Jr., of the Mallinckrodt Chemical Works; The Water Supply of St. Louis, by Mr. G. G. Black, engineer in charge of distribution, St. Louis Water Department; Commercial Features of Engineering, by Mr. W. A. Layman, president of the Wagner Electric Mfg. Co.; The Manufacture of Electrical Machinery, by A. H. Timmerman, chief engineer, Wagner Electric Mfg. Co.; Modern Boiler Practice, by Mr. E. R. Fish, secretary of the Heine Safety Boiler Co.; The Handling of Construction Work, by Mr. A. P. Greensfelder, secretary of the Fruin-Colnon Construction Co.; Engineering Appraisals, by Mr. M. L. Holman, past president, American Society of Mechanical Engineers.

## EXPANSION AT CORNELL UNIVERSITY.

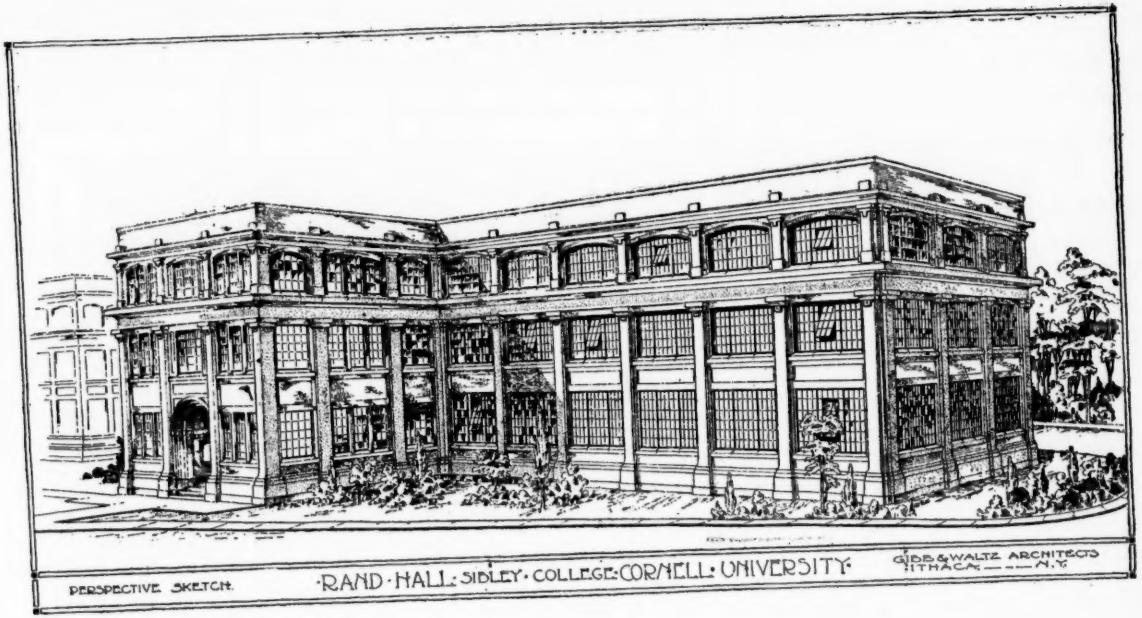
BY ALBERT E. WELLS,
Superintendent of Shops, Sibley College, Cornell University.

For many years the Sibley College of Mechanical Engineering (which includes electrical engineering) has had buildings inadequate for the proper accommodation of the thousand or more students who have crowded its shops and laboratories. A few years ago the trustees appointed a special committee to consider ways and means for providing ampler facilities. The first chairman of this committee was the late Mr. Walter C. Kerr, president of Westinghouse, Church, Kerr and Co., and the work of the committee was completed under the chairmanship of Mr. John H. Barr, consulting engineer of the Union Typewriter Co. The committee prepared tentative plans for a number of buildings and after much discussion by trustees and faculty, with suggestions from alumni, the scheme of expansion shown in the illustration was adopted. When the plan was approved no money was in sight to permit the putting of the plan into operation, but soon thereafter a friend of the College donated the first building in the series, which will be known as the Rand Shops.

This new building which will house the machine and pattern shops is now completed, and the installation of the equipment is being pushed as rapidly as possible. The intention is to have these departments in their new quarters by the close of the present college year. This building, which is a memorial to Jasper Raymond Lang, Addison Crittenden Lang and Jasper Raymond Lang, Jr., is 169 ft. by 50 ft. with a wing 30 ft. by 45 ft., all having three floors. The construction is a steel frame with brick pilasters and curtain walls and concrete cornices; floors and roof also being of reinforced concrete. Lighting is liberally provided by means of steel-sashed windows which are separated only by the pilasters necessary




Proposed arrangement of Sibley College Buildings including new shops and laboratories which will be added as the funds become available. Rand Hall on the extreme left was dedicated on May 23d.



PERSPECTIVE SKETCH. ·RAND·HALL·SIBLEY·COLLEGE·CORNELL·UNIVERSITY· GIDE & WALTZ ARCHITECTS ITHACA ——— N.Y.

to support the upper structure. All offices of administration, store-rooms, toilet-rooms and locker-rooms are located in the wing, leaving the entire main building available for shop use. In general design the building corresponds to modern factory construction, with an exterior of considerable architectural beauty, comparing favorably with any of the Cornell University buildings from this point of view. Special attention was given to the location of locker and wash rooms, which are in the wing and lighted from three sides. This is a departure from the usual plan of locating these rooms in a basement. There is also provided an emergency hospital room, with equipment to care for minor injuries. Handling of supplies and equipment will be facilitated on the ground floor by a Hunt industrial railway and a Niles electric traveling crane, while the two upper floors are served by an Otis elevator of two tons capacity. The shafting throughout the building is carried in ball and roller bearings, in rather short lengths, each driven by its independent motor. Several machines in the machine shop are direct-driven.

On the ground floor is located the machine department, with the machines arranged in groups, each group to accommodate ten students under the supervision of an instructor, who has made a special study of the machinery in his group. The students will be assigned to these groups, and at certain periods the sections will be rotated so that all students will receive the specialized instruction in each group to better advantage than under the old system of instruction. The machine groups are: (*a*) Lathes, (*b*) milling machines, planers and shapers, (*c*) turret machinery and grinding, (*d*) special machines and the use of manufacturing jigs and fixtures. As each instructor is responsible for but ten students, close personal contact between instructor and students is assured. The results attained under this system, which has been tried out to some extent in the old shops, has proved its effectiveness. This method of giving instruction was decided on after a thorough study of several schemes which are used extensively in other technical schools. Its advantage over the

auditorium or lecture room demonstration method lies in the fact that the instruction is actually given to the individual student at the time he needs it, that is when he is doing the work or exercise involved, as against a demonstration to a rather large body of students, many of whom may not be able to do the particular operation demonstrated for several days or weeks. There is nothing in this method of instruction which holds the students back to the rate of progress of the slowest in the group, for each student in a given group may be engaged on a different problem and the tendency is for each individual who has the mechanical ability to progress far beyond any standards which might be set up for all students to meet.

As the aim of college shops is not so much to develop manual skill as to broaden engineering knowledge and to outline the economics of manufacturing, a considerable portion of the equipment of groups (*c*) and (*d*) is operated on commercial product under high-grade manufacturing conditions. Work in this department is paralleled by a lecture course on the "Principles of Manufacturing," in which factory organization, management, cost-keeping systems, pay systems, etc., are discussed at some length. The work given in this course in the junior year is continued in the senior year by a two-hour lecture course, which deals with the further details of manufacturing principles, with reference to the broader problems of industrial organization. In this senior course the modern methods of factory organization and operation with their correlated problems are more fully discussed; the student having back of him an excellent foundation based on the work of the junior year.

The top floor of the building is occupied by the pattern shop, which is the best lighted floor of the building. In addition to the side windows there is provided a north exposure saw-toothed skylight. The underlying principles of instruction are the same in this department as in the more advanced work in the machine shop. As, however, the students have but recently begun their sophomore work in the college and

have had no engineering instruction at all the work is much more elementary in scope.

The second floor of the new building will be occupied for the present by the advanced laboratory of the department of electrical engineering. This laboratory is at present housed in sundry odd corners about the College buildings. Eventually the Department of Electrical Engineering will have a modern building of its own and the space in the Rand building will be used for shop expansion.

## THE TECHNICAL DIRECTOR.

BY WINSLOW H. HERSCHEL,

Assistant Professor of Mechanical Engineering, University of Maine.

Students who are preparing for the higher engineering positions are inclined to think that some of the more elementary studies are unworthy of their attention. For example, a student will remark that there is no use for him to trouble himself with learning to make a neat-appearing drawing, because, after he graduates, he can hire some cheap man to do that sort of work. A writer in a recent number of the BULLETIN seems to have fallen into the same error when he argues that it is not necessary for an engineer to be a good mathematician, because "the civil engineer who designs a bridge across a river can employ a mathematical artisan at $3.00 per day to compute the size of every member of the structure." Expressed in general terms, the philosophy seems to be, "A man can hire another to do for him, anything he can not do himself." Whatever truth there may be in this theory does not need to be emphasized, because students may always be relied upon to keep the instructor reminded of this point of view.

What I believe to be a much truer philosophy, is, to quote the words of an employer, "A man should be able to do the work of any man under him." Responsibility can be delegated only to a limited extent, and the man higher up is held to account for his choice of subordinates. In the case of the consulting engineer who is in charge of the design of a bridge, he may, it is true, employ a man to make his calculations; but if the bridge should fall, the employee might lose his position, but it is the consulting engineer who would be held responsible and whose reputation would suffer. The engineer who can not do the work of those under him, can not properly

select his subordinates. He has but little protection against their incompetency or dishonesty, and is often at a loss whether to accept or doubt their reports upon which his own actions must be based. In a certain case of an engineer making repairs on a dam, he employed divers to investigate the extent of the damage. Doubting the accuracy of their reports, he went down in a diving suit and satisfied himself of the truth of the matter.

The statement of our philosophy is of course somewhat exaggerated, for it is not always possible for a superior officer to do the work of all his men. A general need not necessarily know how to play on all the instruments in the band. Yet the rule applies very well to the chief executive of a manufacturing establishment. He may be called president, secretary, treasurer, or a variety of titles, but, in order to indicate his true function, let us call him the technical director. He is the man who has to unite financial and technical considerations in deciding upon broad lines of policy. Suppose, for example, he must decide whether or not his shop shall undertake the building of gas engines. He need not know how to design every detail of a gas engine himself, but he should know enough about designing to make a pretty shrewd guess as to whether his designer had or lacked ability. He would have to know something about shop processes and the operations of his systematizing department in order to judge whether his shops would be able to turn out the engines promptly and economically. Even when convinced that his design was good and his shop costs reasonable, he would have to decide from a knowledge of the probable demand and competition whether his firm had a chance to enter the market. The responsibility would be his, he could not hire another to relieve him of that, and if he made a mistake he would have to suffer for it.

The student's philosophy has an unfortunate effect not only on his work at college, but on his attitude toward his employer. It makes him reluctant to put on greasy overalls because they imply what he considers menial labor for one of his scholastic attainments. It makes him usually think, and sometimes tell

his superiors that the work he is engaged upon is not suited to his ability. Consequently employers have come to prefer that someone else shall employ a college man until a year or two of contact with real life and work has somewhat modified his views.

There is a place and equally necessary work for schools with widely different ideals and courses of study, but the problem which I wish to consider is the work of a school which aims to prepare students to ultimately fill the highest positions in mechanical engineering. By highest positions we may mean those executive positions which have to do with money as well as men. Not only do those who deal with money, as a general rule, receive higher compensation than those who deal with materials or with men, but they also obtain positions which furnish the most agreeable kind of work. There is thus ample reason for aspiring to the higher positions without regard to their money value.

Engineers used to be considered as the servants of bankers or lawyers, and no one ever thought of appointing them to important positions on commissions as is so frequently done at the present time. The high executive positions in a manufactory used to be filled by promotion of stenographers and bookkeepers from the commercial department. Now, with the increase in the complexity of manufacturing operations, it is becoming more and more common to choose the technical director from the designing, construction or systematizing departments.

It can not be too strongly emphasized that students can not be fitted to take, upon graduation, anything but minor positions. It is unreasonable to expect within the time available to fit them to be technical directors at once. They can only be given such training as will serve as a suitable foundation on which to build. It should also be admitted that all men are not suited by natural ability to become technical directors by any amount or kind of training. It is a case of the survival of the fittest, those who are better suited to something else dropping out, so that no school expects to graduate as many

students as enter with the freshman class. The best that can be done is to so arrange the curriculum that those who leave at any time during the course will have spent their time at school to the best advantage.

As matters now stand, too often the student who can not afford to continue, or has not the ability to continue his course to the end, is sacrificed for the benefit of those who remain. If, for example, a boy, leaving school as soon as allowed by law, starts in as an elevator boy, he may remain an elevator boy for the better part of his life, being fitted on leaving school for nothing better, and having little opportunity for gaining the knowledge that would fit him for a higher position. Too often also in the high schools, those who have never hoped to go to college are sacrificed for the sake of the comparatively few more fortunate, and they leave the schools prepared only for a career which is for them unattainable. The same thing may happen in the technical schools. After the first year or two a student may find that he has not the financial or mental ability to pursue his studies further; that he must give up the idea of ever being a technical director, but that he is not prepared to fill any minor position. Such a student would have done better to have gone to a trade school, or to some school like the Pratt Institute, which aims, in a two-year course, to train its students to become foremen.

For a technical school which aims to prepare students to become eventually technical directors, there must always be a compromise between what best serves this purpose, and what will enable the student to earn a living directly after graduation. Those studies which help toward the latter object, enable a student who is forced to drop out of the course to support himself, and this would be an argument for giving these studies as early as possible in the curriculum. Some schools, like Worcester, give considerable attention to shopwork, and this enables a graduate to fall back on his ability as a mechanic in case of need.

In the majority of technical schools, the curriculum in mechanical engineering seems to be arranged to prepare stu-

dents to become designers, neglecting very largely the other avenues of approach to the position of technical director. If a student drops out after his freshman year he finds that his mechanical drawing has fitted him to be a tracer at most. It is unfortunate that the word draftsman is used to cover the positions of tracer, detailer, designer and checker. On the one hand it makes a student look down upon drafting when he considers it as merely knowing how to draw, and does not realize that a so-called draftsman may hold a very responsible position as a designer. On the other hand it leads him to think he is qualified to hold any position of "draftsman" as soon as he has passed his freshman drawing. In reality if he has become a really good detailer by the time he is through his senior year, he has done well. With this as a foundation, if he has done fairly well in the other college studies, there is no reason why he should not in time become a good designer or chief draftsman. But his progress toward this goal would probably not be so rapid as that of one trained in a European technical school where much more time is given to machine design, and one year of practical work in a commercial shop is required as a prerequisite for graduation.

When the former student has worked his way up to the position of chief draftsman, he begins to find that there are other departments of a manufactory of which he is ignorant, and of which he must be informed before he can rise further. The student who starts in as a mechanic has a somewhat more practical experience. He is informed concerning two of the avenues of promotion, that of the shop from his experience, and that of the drafting room from his college work. We must believe with Professor Furman, who made an exhaustive investigation of the careers of graduates of Stevens Institute, that a student starting in as a mechanic, or who has had shop experience previous to his technical training, is much more likely to reach a high executive position, passing through the positions of foreman and shop superintendent.

The systematizing department, the third avenue of approach to the position of technical director, is unknown alike

to the student who starts in the shop, and to him who starts in the drafting room. This department is under the charge of the works manager who has under him such men as the shipping and receiving clerk, storekeeper and shop order tracer. Few students think of entering this department because they assume that the proper place for them is in the designing or testing departments, and they realize more or less clearly that their school training has given them but slight preparation for this promising field of employment.

This department would offer great opportunities to the college graduate if he were prepared to enter it. It employs a larger number of men than find employment in the drafting room, and work must go on in good times and bad. In dull times no new designs are made in the drafting room, and often the force of employees is greatly reduced, but mechanics are more difficult to procure than draftsmen, and an employer thinks twice before discharging a good one. Moreover, in order to keep the mechanics at work, the systematizing department must be kept working full time.

The introduction of efficiency engineering or scientific management necessitates a corresponding increase in the work of the systematizing department. As scientific management is introduced into more and more shops, there will be a steady increase in the demand for men to fill the new positions. Even at present, employers find the greatest difficulty in finding suitable men to fill positions in this department. The technical schools do not even attempt to train men to fill them. The manufacturers can not import men from abroad for the systematizing department, as they do for the drafting room, because foreign training in shop management gives but little help in understanding American conditions. A foreign designer who can calculate that a shaft must be say 60 millimeters in diameter, has little difficulty in determining the proper diameter in inches, but a knowledge of the cost of turning that shaft in Germany would be of little help in determining shop costs in the United States.

The systematizing department furnishes perhaps the best

preparation for the position of technical director. If a student at college should be given only enough knowledge of this department to enable him to enter it, say as shop order tracer, he should then have no difficulty in advancing. His work will keep him in touch with both the shop and the drafting room, and his shop and drawing room work in college should be sufficient to enable him to make the most of his opportunities, which a man entering the systematizing department without his training could not do. In trying to find causes for delay in getting work through the shop, he will learn how much of the trouble is due to the inability of the mechanics to read drawings, and how much to the inability of draftsmen to make drawings which can be understood. Thus his knowledge of both shopwork and designing will be kept fresh. At the same time he will be acquiring a training in the more commercial aspects of his own department. By the time he has worked up to the position of works manager, he will probably have had a much broader training than either the superintendent or the chief designer, his natural competitors for the position of technical director, and will be better qualified than they for the position. For according to our philosophy, the technical director should be able to do the work of any of his subordinates.

It is not my purpose to attempt to lay out a curriculum best suited to prepare a technical graduate to enter the systematizing department. The details of a suitable course in accounting, statistics, business methods and scientific management should not be difficult to arrange, when once it is seen that this department offers not only the best field for work directly after graduation, but also the brightest prospects for advancement to the chief executive position of technical director.

# MECHANICS FROM THE FREE BODY STANDPOINT.

BY SCOTT B. LILLY,

Assistant Professor of Engineering, Swarthmore College.

A comparison of the curriculum of an engineering school twenty-five years ago with that of the same school today would reveal many interesting facts. The most astonishing feature would be the number of new courses which have been added during that time. It is the men who were studying engineering about twenty-five years ago, who today are doing those things in engineering which will make this decade famous in history. Such an examination would tend to show that the necessary qualifications for success lie not in the study of a multitude of subjects, but in the mastery of a few. Of all of the work pursued by the undergraduate, there is none from a technical standpoint equal in importance to the study of those principles of mechanics which apply to engineering problems. If these principles are thoroughly understood, they enable an engineer to go to the root of any design. He knows upon what his results are based. If they are not thoroughly mastered, the feeling that a design slightly out of the ordinary may be wrong, will never leave him.

Then, the purpose of the courses in mechanics should be to give the engineering undergraduate a knowledge of principles rather than a knowledge of formulæ; to enable him to separate a machine or structure in such a way as to reveal all dangerous sections, all points of greatest pressure; to enable him to recognize quickly the most dangerous load that could be applied, so that he can go behind his formulæ and reduce his problem to fundamental principles.

It is the purpose of this article to show how a method presented in some text-books on mechanics, and called by them "The Free Body Method," serves to help men to that grasp

of principles which is so desirable; to show that this conception thoroughly mastered serves equally well whether the problem be one of statics, dynamics, or flexure. Its relation to each of these subjects will be outlined and its application illustrated with a problem. It might be added that this method can be used in hydraulics as well, but that will not be touched upon in this article.

"The Free Body Method" consists in making a sketch of the body, or part of the body, that is under consideration, and then, by properly directed arrows, representing on the sketch all external forces which act upon the body in question. In this way a picture of the body with every force acting upon it is obtained. The next step is to form equations based upon the fact that the body is at rest, or that it possesses a certain type of motion, or that its velocity has changed a certain amount in a given time or upon other considerations which may be pointed out. *If as many equations can be formed as there are unknown forces, the solution can be reached directly.* If the number of equations that can be formed is one less than the number of variables, each of the variables can be expressed in terms of one, and a solution obtained by trial.

Before the student attempts to employ any method to solve problems in mechanics, he should have a clear conception of force. He should realize that nothing is *a force* whose effect cannot be measured by a properly placed spring balance, that while gravity, and electrical attraction and repulsion act at a distance, the majority of forces act by contact, and that those *forces which do act by contact will be normal to smooth surfaces and will have a tangential component if the surface is not smooth.* If the pressure is transmitted by a pin, he should realize that both the amount and the direction are unknown except in particular cases, the most important of these exceptions being that in which a bar is subjected to pressure by two pins only. Then, *if the bar is prismatic,* and the weight of the bar itself be neglected, the stress would lie along the axis of the bar, and hence would fix the direction of the force. In determining the forces which act upon a given

bar or body, the student should keep in mind the various *things necessary to determine a force,* namely its magnitude, direction, and point of application. The point of application of the weight is at its center of gravity, the point of application of forces which act by contact would be at the center of pressure. Therefore the student can, in general, immediately decide upon the point of application of all forces. As has been pointed out above, the direction is fixed if the surface of contact is smooth, or if it is a two force piece. *If the surface is rough,* the statement of the problem will usually contain sufficient information to determine the relation of the tangential to the normal component. If more than two forces act upon a piece which is a part of a pin-connected structure, the pressure brought by that piece upon another may be unknown both in amount and direction, and then it is only known that the pressure will pass through the center of the pin. In that case, it will usually be desirable to replace the unknown force acting in an unknown direction by two unknown forces acting in known directions. Many times this will materially lessen the labor involved. All of these things must be thoroughly understood by the student before he can correctly represent forces.

It is equally essential that the student should have a complete and thorough understanding of the principles of static equilibrium before he undertakes to solve any problem in statics. He should know that *practically all problems can be reduced to a system of non-concurrent forces in a plane,* and that for such a system there are three conditions of equilibrium. Each of these conditions should be a real, vital, concrete fact, and not merely an equation obtained in some vague way from some unknown source. A great many students can write the algebraic sum of the $Y$-components equal to zero, and not realize that because there is no motion parallel to the $Y$-axis, the algebraic sum of the forces parallel to that axis must equal zero. If they know the meaning of such a summation, they are much less liable to introduce wrong forces.

When the student has clearly in mind how to recognize and represent a force, and understands the conditions of equilibrium, he is ready to solve problems in statics. When such a problem is presented to him, let him *examine each part of the structure,* first deciding how many forces are acting upon each part. He should carefully *note each two-force piece* because from them he can obtain the direction of the action of that piece upon those that it connects. He should *note all smooth surfaces,* because they also fix the direction of the action between the surfaces and the pieces in contact with them. *Each part acted upon by more than two forces* must be considered by itself, or, as a "free body," and the beginner, at least, should sketch each of these pieces, and represent by arrows the forces which act upon the piece under consideration. The student must then decide which of these parts to solve first. This he can do by remembering that if the part under discussion is acted upon by a system of non-concurrent forces in a plane (the most common case) he can solve only when he has at least one force known in amount and direction and not more than three unknown forces, assuming that he replaces all forces unknown in amount and direction by two forces known in direction. Taking the sketch of such a part, which may or may not be the structure considered as a whole, he can usually find such a point for the center of moments that one, and usually two, of his unknowns will have a zero lever arm. Then by summing his $X$ and $Y$ forces, he can obtain equations from which the other two unknowns can be determined.

*The greatest difficulty experienced by the student* when he has succeeded in gaining the ability to recognize forces, is that he attempts to include forces which are not external to the part under consideration, but are the action of a part of the body under consideration upon another part of that same body. Then if he fails to include both the action and the reaction, he is in difficulty. He should realize that there must be action between each minute part of the body in order that it remain intact. The reason it is possible to neglect

such internal actions is because both action and reaction would have to be included if they were considered, and consequently they would immediately annul each other and drop out. If the student would keep these things in mind, he would have less difficulty.

*The student then would have a definite method of procedure in solving a problem in statics.* The steps he would take in his solution are these.

1. Examine the problem carefully, noting all known forces, all two-force pieces, smooth surfaces, and all statements which would determine the amount or direction of any force.

2. Sketch all parts acted upon by more than two forces, representing all forces which act on the part in question, forces unknown in both amount and direction being represented by two forces known in direction.

3. Choose a part that has at least one force known in both amount and direction, and not more than three unknowns if the system is non-concurrent, or two unknowns if the system is concurrent.

4. Write out equations based upon the conditions of equilibrium.

5. Solve for the desired unknowns.

6. Select another part which now has the desired number of knowns and unknowns, and continue until all are determined.

*The advantages claimed for this method of solution are these.*

First, it leads to accurate thinking. If a man has to decide upon the action on a bar or piece, and then represent his decision in definite form, which he does when he represents the force by an arrow, he is much less apt to make a mistake in his thinking.

Second, there is a definite picture in front of him of the problem in hand, so that he is not apt to leave out a force or to include one that does not act upon the part in question, and, finally, there are fewer opportunities for blunders, such as getting distances wrong, or making mistakes in signs.

Dynamics presents a different problem, but it can readily

be reduced to practically the same form. In the case of translation, the resultant force equals mass times acceleration, and in the case of rotation about a fixed axis through the center of gravity, the sum of the moments about that axis is equal to the angular acceleration times the moment of inertia of the body with respect to that axis. These facts will not be discussed here, and since the majority of the problems in dynamics with which the engineer has to deal are either of translation or rotation about a fixed axis, the case of combined rotation and translation will not be considered.

Then in a case of translation the body is taken as a free body, and the forces represented in exactly the same way as would be done if the body were at rest. The solution is arrived at in practically the same way as in statics. There is, however, this difference. Whereas before the algebraic sum of the components was placed equal to zero, the sum of the components parallel to the motion must now equal the mass of the body times its acceleration. All of the other summations will be equal to zero as before. In statics, the conditions of equilibrium only were used to obtain values of the unknowns, but now the motion of the body must be considered in order to arrive at the value of the acceleration. To do this, it is best that the student work always from the differential equations of motion, even though the motion be uniformly accelerated and all relations that he may need can be derived without directly referring to them. The object of this is to try to aid him in avoiding that common pitfall of always using the equations for uniformly accelerated motion whether the acceleration is uniform or not.

Similarly, if the motion be that of rotation about a fixed axis the center of gravity of the rotating body being in the axis of rotation, the body can be taken as a free body and again all of the conditions that would be available if the body were at rest can be used, the only difference being that when the sum of the moments about the axis of rotation is taken instead of placing that summation equal to zero, it is placed equal to the angular acceleration times the moment of inertia of the body with respect to that axis.

If the body be such that it can be considered a material point, as for instance, the simple pendulum, the point can be considered as a free body, and the algebraic sum of the forces acting upon the point tangentially and normally can be taken. Instead of placing these summations equal to zero, however, as would be done if the point were at rest, the sum of the forces parallel to the tangent are placed equal to the mass times the tangential acceleration and the sum of the forces parallel to the normal equal to the mass times the normal acceleration.

It is evident then that if the student once attains the ability necessary to recognize forces and can make a sketch with the proper forces correctly represented, he has gone a long way toward obtaining the solution of his problem. These few simple principles will aid materially in the solution of many problems in dynamics.

There is no part of applied mechanics in which the free body is of more service than in mechanics of materials. While the principles involved are those of statics, the free body will be found most serviceable in keeping the various forces clear in the mind of the student. So far the free body has been used with rigid bodies only. It will now be shown that it applies equally well when the bodies change form under the action of stress.

The first case that the student investigates in mechanics of materials is that of a bar under tension. The free body serves even in that simple case to make clear the distribution of the stress over the cross section. The bar is a two-force piece. If it is cut, the resultant of the forces on the cross section must coincide in amount and line of action with the force which acted on the part taken away. Therefore, if the force is axial, the stress must be uniformly distributed; if the force is eccentric, the student immediately grasps that it must act through the centroid of the stresses.

By considering the forces acting upon a differential parallelopiped, the student can easily see why shear exists on oblique sections when a bar is in tension. This method of dividing

a bar into elements of that kind can be employed when showing the student the effect produced by combined flexure and torsion, or flexure and direct stress. *When the student can take a differential element* and can show the forces acting upon every part of it, and can then apply the conditions of equilibrium to it, it would seem that there need be no uncertainty in his mind as to the effect produced by combined stresses. It ought to remove any vagueness that might remain as to what effect the combination of the various actions would have.

*Flexure* lends itself even more readily to the free body method. When the student learns to solve a beam using this method, he is entirely independent of any formulæ. *The various steps that would be taken in investigating the strength of a beam loaded with both concentrated and distributed loads (Fig. 1) will now be given.*

1. Consider the whole beam as a free body (Fig. 2) and get the reactions of the supports. There can be no uncertainty as to the relations which must exist between the loads and reactions if the whole beam is taken in this way.

2. Take a free body $x$ feet long measuring from the left end of the beam (Fig. 3), letting $x$ take any value from zero to the distance to the first concentrated load. Represent the reaction, the part of the load on the free body, and the internal stresses in the cross section.

3. Take the sum of the vertical forces and place it equal to zero. Solve for the shear, and obtain the equation of the line joining the ordinates of the shear diagram.

4. Take $\Sigma M = 0$ with the center of moments at the neutral axis, and solve for the moment of the stress couple. This gives the equation to the moment diagram. If there were no concentrated loads, that would complete the shear and moment diagrams, but as there are concentrated loads, separate expressions for the shear and moment between each of the concentrated loads must be obtained since the curve can be plotted for that distance only for each free body.

5. Take a free body from the left end up to the point where

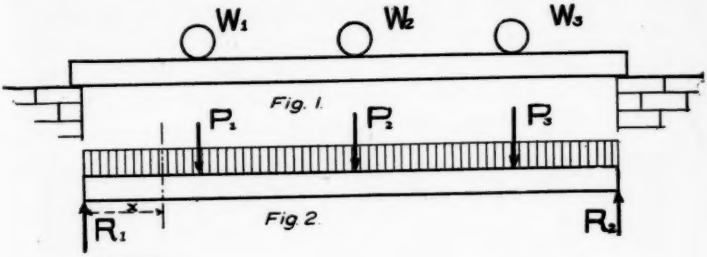



Fig. 1.

Fig. 2.

Fig. 3.

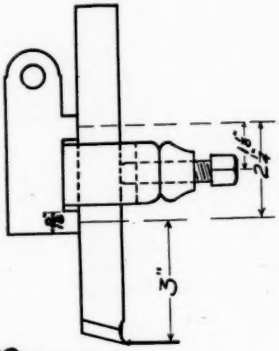



Fig. 5.

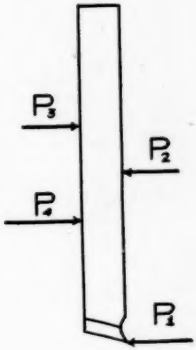



Fig. 6.

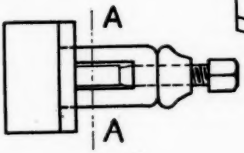



Fig. 7.

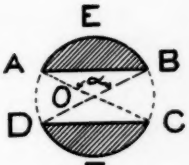



Fig. 9.

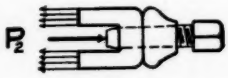



Fig. 8.

the shear passes through zero, and obtain the maximum moment, by taking moments about the neutral axis of the section.

6. Place the maximum moment equal to the flexure formula and obtain the maximum stress in the outer fiber.

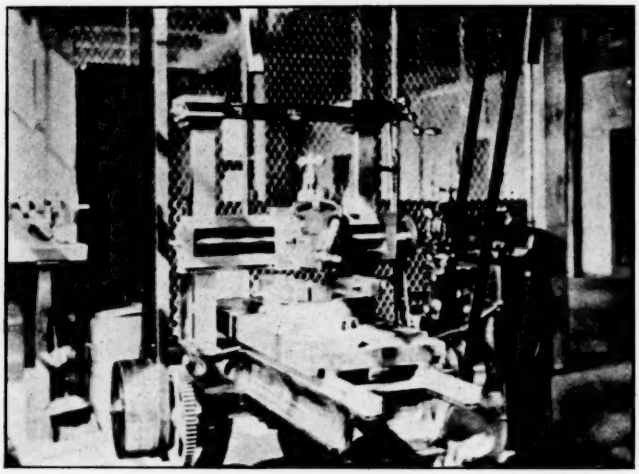


Fig. 4.

The method just outlined is for solving a beam when the loads and span are known. The free body method is of even greater service when the problem is not of the standard form. For instance, beams with overhanging ends present many problems which would be much simplified by the use of properly chosen free bodies. To state one, this method would make it much easier to find what length of overhang will cause the moment over the support to be equal numerically to the maximum moment between the two supports, that is, this method constantly avoids the use of rules and formulæ for determining the desired quantities, and always brings the student back to fundamentals, and hence develops his ability to solve problems of all kinds.

In order to show that the free body method is practical and serviceable, its use will be illustrated by investigating the stresses in the various parts of the planer shown in Fig. 4. The planer has been taken as an illustration because it affords an example of nearly all of the different kinds of stresses, and because the free body method has not been as much used in investigating machines as it has in finding the stresses in framed structures. The force with which the metal resists the cutting action of the tool will be traced through the entire machine.

The tool, tool post, and tool block are shown in Fig. 5, and in Fig. 6, *the tool* is represented as a free body. There are four pressures acting upon it (see Fig. 5 and Fig. 6), the pressure of the metal, $P_1$; the pressure of the set screw, $P_2$; and the pressures of the two lugs of the block against which the tool is pressed, $P_3$ and $P_4$. It is assumed that the heaviest cut that the tool will take, will cause a resistance of 1,000 lbs., that is, $P_1 = 1{,}000$ lbs. The maximum pressure which can be brought by the one-half inch set screw is 8,000 lbs., that being the force which would cause rupture. It will be assumed then that 4,000 lbs. is a larger force than would ordinarily be brought to bear by the set screw, and that value will be used in our computations, that is, $P_2 = 4{,}000$ lbs.

Then taking $\Sigma M = 0$, with the center of moments at the point of application of $P_3$, there is obtained

$$P_1 \times 5\tfrac{1}{4}'' + P_2 \times 1\tfrac{1}{8}'' - P_4 \times 2\tfrac{1}{4}'' = 0;$$

or, substituting numerical values for $P_1$ and $P_2$,

$$1{,}000 \times 5\tfrac{1}{4}'' - 4{,}000 \times 1\tfrac{1}{8}'' - P_4 \times 2\tfrac{1}{4}'' = 0; \qquad (1)$$

$$\therefore P_4 = 4{,}330 \text{ lbs.} \qquad (2)$$

Then taking the sum of the horizontal components and placing it equal to zero ($\Sigma X = 0$),

$$P_3 + 4{,}330 - 4{,}000 - 1{,}000 = 0; \qquad (3)$$

and

$$P_3 = 670 \text{ lbs.} \qquad (4)$$

The tool is one half inch thick, and the rib is $\frac{9}{16}''$ wide. Therefore, the area pressed on equals $\frac{9}{32}$ sq. in. *The bearing pressure on the lower lug is,* then, $4{,}330 \div \frac{9}{32}$, or 15,420 lbs. per square inch, which is high.

The stresses in the *tool post* itself must also be investigated. This is under a tension equal to the pressure brought by the set screw, namely, 4,000 lbs. In Fig. 7, the tool post is shown connected with the block, and in Fig. 8 that part of the tool post to the right of the section *A–A* which passes through the smallest section is represented as a free body. The area of that section, shown to a larger scale in Fig. 9, equals the area of the sectors *AEBO* and *DOCF* minus the area of the triangles *AOB* and *COD*. The angle $\alpha$ is about 128°. Then the net area equals $2\ (.6086 - .2025) = .812$ square inches, and the intensity of the stress equals $4{,}000 \div .812 = 4{,}925$ lbs. per sq. inch, a safe value if the tool post is made of steel.

The *tool block*, shown as a free body in Fig. 12, is next taken. From an inspection of Fig. 10, it is evident that it is subjected to a pull $P_2$ by the tool post equal to 4,000 pounds, and to the pressures $P_3$ and $P_4$ on the lugs equal to 4,330 pounds and 670 pounds respectively. Besides these, there is the unknown horizontal force $P_5$ on the pin at $A$, and the horizontal pressures along the back of the block, whose resultant is $P_6$. There will be fewer forces to handle, if the free body shown in Fig. 11 instead of the one in Fig. 12 is taken.

Therefore, considering Fig. 11, $P_5$ will be horizontal and will pass through the center of the pin. It is assumed that the block is fitted accurately, and that it can therefore be assumed that the pressure is uniformly distributed over the back of the block. Then $P_6$ will be applied at the center of the area and its lever arm about the center of the pin will be one and one half inches.

Then taking $\Sigma M = 0$, with the center of moments at the center of the pin, the following will result,

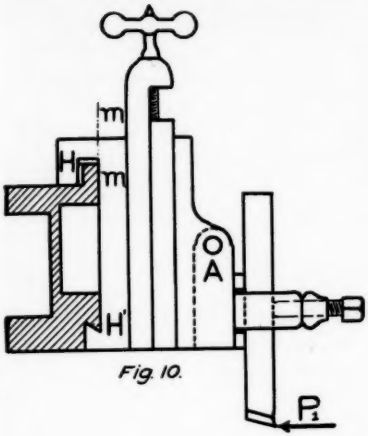



Fig. 10.

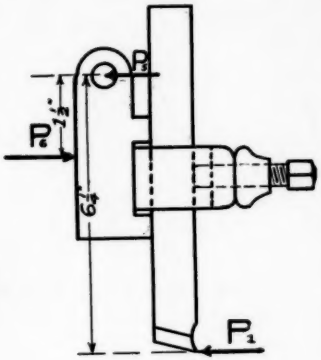



Fig. 11.

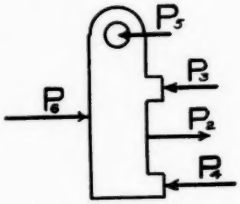



Fig. 12.

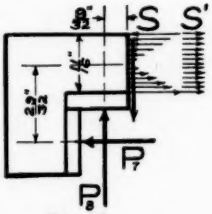



Fig. 14.

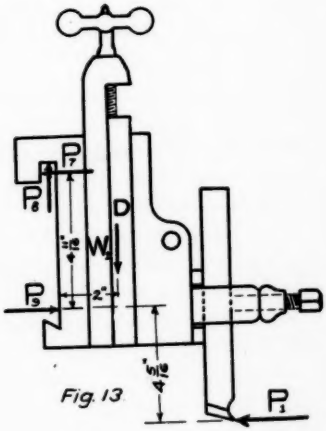



Fig. 13

$$P_1 \times 6\tfrac{1}{4}'' - P_6 \times 1\tfrac{1}{2}'' = 0.$$

Substituting 1,000 lbs. for $P_1$,

$$1{,}000 \times 6\tfrac{1}{4}'' - P_6 \times 1\tfrac{1}{2}'' = 0;$$

$$\therefore P_6 = \frac{6250}{1.5} = 4{,}170 \text{ lbs.}$$

Taking $\Sigma X = 0$; $P_6 - P_5 = 1{,}000$;

$$\therefore P_5 = 3{,}170 \text{ lbs.}$$

Since the entire area of the block, eight and one half square inches, is bearing upon the supporting piece, the unit pressure is very small. It actually equals $4{,}170/8.5 = 490$ pounds per square inch.

Considering now the pin at $A$ (Fig. 10), which holds the block in place and resists $P_5$, the 3,170 pounds of horizontal pull, it will be found, neglecting the weight of the block and pin which is very small, that the intensity of shearing stress induced is equal to the total stress divided by the area of the pin

$$= \frac{3{,}170}{2\left[\frac{\pi}{4} \cdot (\frac{1}{2})^2\right]} = 8{,}080 \text{ lbs./sq. in.}$$

That part of the *cross head* which slides on the cross rail (marked $HH'$ in Fig. 10) and transmits these loads to the cross rail, is now to be considered. In Fig. 13, all of the cross head has been taken as a free body. Let $P_7$ represent the horizontal force, with which the cross rail acts upon the cross head. (See Figs. 10 and 13.) $P_9$ is the pressure of the lower part of the cross rail, and $P_8$ the vertical action of the cross rail on the cross head. In each case it has been assumed that the pressure is uniformly distributed and hence acts at the center of the area. The only other forces external to the cross head considered as a free body, are the weight of the cross head, $W_1$, which equals 42 pounds, and which will be assumed to

act at the point $D$ (see Fig. 13), and the pressure $P_1$ of the metal on the tool, which equals 1,000 pounds and acts three inches below the cross head. To find the amount of $P_7$, the sum of the moments ($\Sigma M = 0$) about the point of application of $P_9$ will be taken. The force $P_1$ has a lever arm about that point of $4\frac{5}{16}''$; $P_7$ has a lever arm of $4\frac{1}{16}''$, $P_8$, one of $\frac{9}{32}''$, and the weight, $W_1$, one of $2''$.

Therefore

$$P_1 \times 4\tfrac{5}{16}'' - P_7 \times 4\tfrac{1}{16}'' + P_8 \times \tfrac{9}{32}'' + W_1 \times 2'' = 0.$$

Giving $P_1$ and $W_1$ their numerical values, the equation becomes

$$1{,}000 \times 4\tfrac{5}{16}'' - P_7 \times 4\tfrac{1}{16}'' + 42 \times 2'' + P_8 \times \tfrac{9}{32} = 0;$$

$$\therefore P_7 = 930 \text{ lbs.}$$

From $\Sigma X = 0$,

$$P_9 = 1{,}000 + P_7 = 1{,}930 \text{ lbs.}$$

From $\Sigma Y = 0$,

$$P_8 = 42 \text{ lbs.}$$

The forces external to the cross head have now been determined. Next the stresses set up in the various parts of the cross head itself must be examined. The stresses in section $m$–$m$ (see Fig. 10) will be investigated first. The part of the cross head to the left of this section is marked $H$ in Fig. 10 and is shown as a free body in Fig. 14. It acts as a cantilever under the action of the force $P_8$ and as a bar with an eccentric load under the action of $P_7$. From Fig. 14, it is evident that the lever arm of $P_7$ about the center of gravity of the section is $\frac{29}{32}''$ and that of $P_8$ is $\frac{9}{32}''$. In Fig. 14, the stress couple has been sketched, and also the direct stress caused by $P_7$. Again these forces may be considered in one plane, and taking ($\Sigma M = 0$) with the gravity axis of the section as the center of moments,

$$P_7 \times \tfrac{29}{32} + P_8 \times \tfrac{9}{32}'' = M,$$

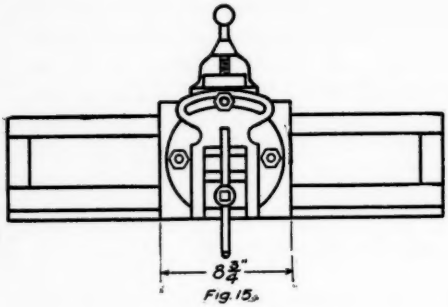


Fig. 15.

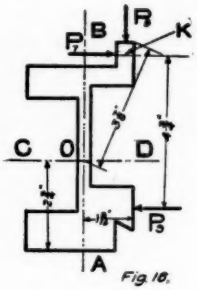


Fig. 16.

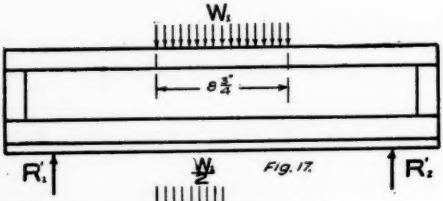


Fig. 17.

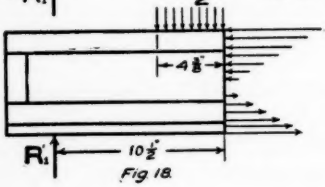


Fig. 18.

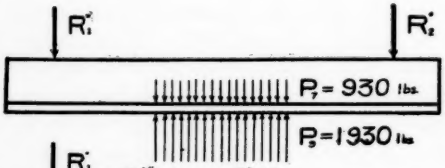


Fig. 19.

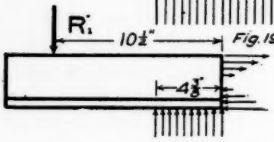


Fig. 20.

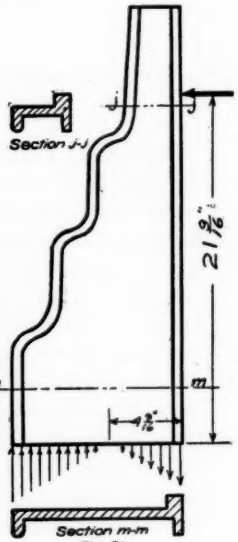


Fig. 21.

where $M$ represents the moment of the stress couple. Substituting $P_7 = 930$ lbs. and $P_8 = 42$ lbs.,

$$M = 860 \text{ inch pounds.}$$

But $M = SI/c$, in which $S$ = unit stress in outer fiber due to moment, $I$ = moment of inertia of the cross section, and $c$ = distance from the gravity axis to the outer fiber. The cross section, being rectangular, $I/c$ equals $\frac{1}{6}bh^2$, in which $b = 8\frac{3}{4}''$ ($b$ is shown in Fig. 15), $h = \frac{11}{16}''$; $\therefore I/c = .689$ in.$^3$ and

$$S = \frac{Mc}{I} = \frac{860}{.689} = 1{,}244 \text{ lbs./sq. in.}$$

Taking $\Sigma X = 0$, letting $S'$ equal the direct tension caused by $P_7$,

$$S' \times bh = P_7 = 930;$$

$$\therefore S' = \frac{8\frac{3}{4} \times \frac{11}{16}}{930} = 156 \text{ lbs./sq. in.}$$

Therefore the total unit stress in the lower outer fiber equals

$$1{,}244 + 156 = 1{,}400 \text{ lbs./sq. in.}$$

There remains to be considered the *bearing pressures of the forces* $P_7$ and $P_9$, of which $P_9$ is the greater. Since $P_9$ acts upon an area of $12\frac{5}{32}$ sq. in. and hence gives a unit bearing value of about 160 lbs./sq. in., it is evidently unnecessary to consider the bearing pressure caused by $P_7$.

The effect of these loads upon the cross rail will now be considered. From Figs. 10 and 15, it is evident that the cross rail is subjected to three different kinds of stress. Its own weight and that of the cross head cause a moment about the horizontal axis $CD$ (Fig. 16). Figs. 19 and 16 show that $P_9$ (1,930 pounds) and $P_7$ (930 pounds) would cause a moment about the vertical axis $AB$, and also cause torsion about an axis perpendicular to the plane of the cross section. It will be assumed that $P_9$ and $P_7$ can be replaced so far as the stresses they will cause are concerned, by a horizontal

force of 1,000 pounds at 0, and a couple, with forces of 930 pounds and a lever arm of $4\frac{3}{4}''$.

It will first be necessary to find the moment due to the weight of the beam, $W_2$, and that of the cross head $W_1$. In Fig. 17, the cross rail has been shown with the weight of the cross head distributed over a length equal to the width of the cross head, namely, $8\frac{3}{4}''$. Since the cross rail weighs 81 pounds, the reaction $R_1'$ due to these two weights will be

$$R_1' = \frac{42 + 81}{2} = 61.5 \text{ lbs.}$$

The maximum moment can be found by taking a free body up to the middle of the cross rail (Fig. 18) and taking moments about the gravity axis. Referring to Fig. 18, $R_1$ will have a lever arm of $10\frac{1}{2}''$; $W_1/2$, a lever arm of $2\frac{3}{16}''$, and $W_2/2$, one of $5\frac{1}{4}''$. Then ($\Sigma M = 0$) gives

$$R_1' \times 10\tfrac{1}{2}'' - \frac{W_1}{2} \times 2\tfrac{3}{16}'' - \frac{W_2}{2} \times 5\tfrac{1}{4}'' = M'.$$

Or,

$$61.5 \times 10\tfrac{1}{2} - 21 \times 2\tfrac{3}{16} - 40.5 \times 5\tfrac{1}{4}'' = M'$$

and $M' = 441$ inch pounds, in which $M'$ represents the bending moment about the axis $CD$ (Fig. 16).

Fig. 19 shows $P_7$ and $P_9$ distributed over a length equal to the width of the cross head. The reactions $R_1''$ and $R_2''$ are each equal to 500 pounds and since the load is symmetrical, the maximum moment will occur in the middle of the beam. Fig. 20 shows the part of the beam to the left of the middle as a free body and from it, it is evident, by taking moments about the gravity axis (Fig. 20), that $M''$, the bending moment, equals

$$M'' = 500 \times 10\tfrac{1}{2}'' - 500 \times 2\tfrac{3}{16}'' = 5{,}312.5 \text{ inch pounds.}$$

Finally, the moment of torsion produced by the couple whose forces are 930 pounds and whose lever arm is $4\frac{3}{4}''$, must be obtained. Since one half of this torsion will be carried by each end of the cross rail, the torsional moment equals

$$\frac{930}{2} \times 4\tfrac{3}{4}'' = 2{,}210 \text{ inch pounds.}$$

The effects of these moments in causing stress can be approximated, but cannot be determined exactly. It is known that the neutral axis of a beam subjected to bending in both the vertical and the horizontal plane, makes some angle with a line at right angles to the resultant of the loads. It is also known that if a prism, not circular, is subjected to torsion, the surfaces originally plane become warped surfaces. The experiments of St. Venant in France would indicate that the little projection marked *K* in Fig. 16 would get little or no stress due to torsion. So, if the moment due to the weight of the beam itself is neglected, and the stresses due to flexure and torsion are combined by the well-known relation for circular shafts, a value will be found for the maximum unit stress which will undoubtedly be larger than the real value. The moment of inertia of that section about the axis *AB* (Fig. 16) which passes through the center of gravity and is 1.56 inches from the edge of the beam, is 6.774 in.[4]

The unit stress due to bending is then

$$S = \frac{Mc}{I} = \frac{5312.5 \times 1.56}{6.774} = 1{,}350 \text{ lbs./sq. in.}$$

The moment of inertia about the gravity axis, *CD* (Fig. 16), is 35.374 in.[4]. Therefore the polar moment of inertia

$$I_p = I_{AB} + I_{CD} = 42.148 \text{ in.}^4$$

and the stress in the outer fiber would be equal to $S_s = Mc_1/I_p$, in which $c_1$ equals the distance to the outer fiber (see Fig. 16) $= 3.875$ in.;

$$\therefore S_s = 4{,}420 \times 3.875 \div 2 \times 42.148 = 200 \text{ pounds per sq. in.}$$

As stated above, this formula does not strictly apply because the section does not remain a plane under torsion, but from the experiments that have been performed, it is known that the maximum stress does not occur in the most distant fiber. Therefore these figures are on the safe side and the stress is less than 200 pounds per square inch.

Combining these stresses by the formula,

$$S_1 = \tfrac{1}{2}S + \sqrt{\tfrac{1}{4}S^2 + S_s^2}$$

in which $S_1$ equals the maximum stress, $S$ equals the stress due to flexure, and $S_s$ equals the stress due to torsion, and substituting the values for $S$ and $S_s$ from above,

$$S_1 = 675 + \sqrt{(675)^2 + (200)^2}.$$

$S_1 = 1{,}383$ pounds per square inch, which would give a factor of safety of about 14 for cast iron.

There remains to be considered the stresses in the vertical frame that supports the cross rail (Fig. 21). The maximum stress will occur when the cross rail is raised as far as possible. The reaction of 500 pounds caused by the 1,000 pounds load will be applied $6\frac{5}{16}''$ below the top. Four and three quarters inches from the top there will be the moment of the torsional couple of 2,210 inch pounds. Since this couple causes a clockwise moment and the load a counter-clockwise moment, the maximum stress in the frame will occur when the tool extends as small a distance as possible below the cross rail. In that case the torsional couple will be reduced to 675 inch pounds. It will cause a stress in a section $4\frac{3}{4}''$ below the top of 135 pounds per square inch. This is so small that the effect of this couple on all of the lower sections can be neglected. In the section at the bottom of the frame the lever arm of the load will be $21\frac{9}{16}''$.

$$\therefore M = 500 \times 21\tfrac{9}{16}'' = 10{,}750 \text{ inch pounds.}$$

$I$ for this section equals 103.7 inches$^4$, and $c$ equals 4.57 inches. Therefore the unit stress

$$S = 10{,}750 \times 4.57 \div 103.7 = 473 \text{ pounds per square inch,}$$

a low value even for cast iron.

It is concluded then that the stresses which exist in this planer are not excessive, and it is now possible to go back through the machine and increase or decrease the metal at each critical point.

It involves very little new theory, to inquire into the amount of power which must be delivered to the planer to cause the tool to move through the metal at a certain speed.

*To sum up the advantages of the free body method* in the study of mechanics, it can be claimed that by making the sketch and representing the forces which act, the student is compelled to form a definite conception of the problem in hand. All problems are more than half solved when their conditions are thoroughly understood. If the free body method served no other purpose, its use would be more than justified. It does more, however. It lessens the chances for numerical error; for taking forces in the wrong direction; and for introducing fictitious forces. It constantly emphasizes the fundamental conceptions and discourages blind memorizing of formulæ. It is absolutely general, applies to nearly all design, and can always be relied upon. Once thoroughly mastered, it makes clear many a disputed point, and assists materially in enabling the designer to bring all of his knowledge of mechanics to bear upon any problem which may arise.